DOCUMENT RESUME

ED 070 615 SE 015 000

AUTHOR	Cox, David C.
TITLE	How to Investigate the Environment in the City: Air and Water.
INSTITUTION	National Science Teachers Association, Washington, D.C.
PUB DATE	72
NOTE	12p.
AVAILABLE FROM	National Science Teachers Association, 1201 16th St., N.W., Washington, D.C. 20036 (Stock No. 471-14630, $0.50)
EDRS PRICE	MF-$0.65 HC Not Available from EDRS.
DESCRIPTORS	*Air Pollution Control; Environmental Education; Experiments; Instructional Materials; Investigations; Learning Activities; *Student Projects; *Study Guides; *Urban Environment; *Water Pollution Control

ABSTRACT

Two significant aspects of the urban environment, air and water, are focused upon in this instructional aid pamphlet. For each component, the range of possible studies is surveyed, together with the state of the situation and associated problems. Sample experiments are suggested and their test procedures outlined. Where special equipment, inexpensive test kits, or chemicals are required or would enhance the investigation, they are described and illustrated. A source list of organizations, periodicals, and publications is also supplied. (BL)

PERMISSION TO REPRODUCE THIS COPYRIGHTED MATERIAL BY MICROFICHE ONLY HAS BEEN GRANTED BY

NEA

TO ERIC AND ORGANIZATIONS OPERATING UNDER AGREEMENTS WITH THE U.S. OFFICE OF EDUCATION. FURTHER REPRODUCTION OUTSIDE THE ERIC SYSTEM REQUIRES PERMISSION OF THE COPYRIGHT OWNER."

INSTRUCTIONAL AID

how to.

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL OFFICE OF EDUCATION POSITION OR POLICY

ED 070615

INVESTIGATE THE ENVIRONMENT IN THE CITY:
Air and Water

David C. Cox *Science Department Chairman / Rex Putnam High School / Milwaukie, Oregon*

For a student or for anyone interested in gaining information and satisfying his curiosity concerning the world around him, the urban environment offers many challenges. At least as many, if not more, than those of the mountain wilderness or blooming desert. The myriad forms of plant and animal life, including man, probably live in a more delicate state of balance in the urban surroundings than anywhere else on earth.

Here we will focus on two significant aspects of the urban environment – air and water. Air, that fragile layer of gases that surrounds the earth and holds the key to matter and energy cycles which support ecosystem earth. Water, that wondrous chemical compound without which biological life as we know it would be nonexistent.

EXPLORING THE URBAN AIR

The range of air-study activities within the reach of students is almost without bounds and has enough variety to touch an interest area for nearly everyone. Individual or class activities may focus on

Air quality (components and their concentration)
Detection (qualitative and/or quantitative) of pollutants, either at the source or in the environment
Examination of the sources of pollutants
Uses of air within the urban environment
Effects of urban use upon the quality of the air
Effects of different qualities of air upon various plants, animals, and materials
Procedures for eliminating or reducing emission of pollutants at their source or prior to use of the air.

The significance of local weather patterns and geography to the quality of the air and the capacity of the atmosphere to disperse pollutants is an exciting multidisciplinary topic. Students can, for example, build working models that will demonstrate the production and effects of a temperature inversion, as well as working models of such devices as electrostatic precipitators.

Through library research students can follow recent studies on the health aspects of air quality as they concern the human urban population.

Moreover, students can work on a variety of individual or small-group projects and then report procedures and findings to their classmates. Many of the subtle relationships that exist within the environment are often most naturally brought out by this type of student involvement and sharing. The more specific the topic undertaken, the more meaningful and useful are the results. Usually, too, the most productive student study is the one closest to home. Often it is an original undertaking, at least in the eyes of the explorer.

For source material students and teachers can call upon the many laboratory guides, manuals, and reference books now available. Some of these are listed on page 11. An ever-growing classroom set of these aids will add a new dimension to the learning atmosphere. Many of these sources will also provide rather detailed instructions for design and construction of apparatus, as well as procedures for achieving a variety of objectives.

The following activities have gained student acceptance and have provided extremely stimulating approaches for examining some aspects of the urban environment. They are relatively crude and open-ended, leaving refinement, degree of sophistication, and extension as a local option.

URBAN AIR POLLUTION—A NEW PROBLEM?

Air pollution is one of the urban area's oldest problems, being reported as early as 61 A.D. in Rome. Reportedly, laws attempting to control air pollution were passed as early as 1273. Are there historically some characteristics of urban growth that may in part explain the long duration of this problem? Do these same characteristics play a role in today's urban growth and development?

Air is essential to our existence and is a necessity in sustaining the biological world in which we live. Approximately 15,000 quarts per day per individual, cycling at the rate of roughly 20 cubic feet per hour, and supplying oxygen and removing carbon dioxide, are required for survival.

SE 015 000

Copyright 1972 by the
National Science Teachers
Association
an associated organization
of the
National Education Association
1201 16th St., N.W.
Washington, D.C. 20036

Stock No. 471-14630

Price 50 cents

Orders of $2 or less
must be prepaid

ADVISORY COMMITTEE

Rolland B. Bartholomew, Chairman
Department of Geological Sciences
The University of Texas, Austin, Texas

Grace T. Williams
Garfield Elementary School
Cincinnati, Ohio

Beatrice J. Elyé
Cleveland Hill High School
Cheektowaga, New York

Michael Fiasca
Portland State University
Portland, Oregon

William B. Robertson
East Mecklenburg High School
Charlotte, North Carolina

NSTA HEADQUARTERS

Mary E. Hawkins
Associate Executive Secretary and
Director of Publications

Sandra Grimm
Editorial Assistant

THE PARTICULATE CONTENT OF THE AIR

In general, air pollutants fall into two large classifications—particulate and gaseous. Dusts and other solid particles come from many sources. Some of the particles are of natural origin, such as particles of dry soil or pollen grains which have been picked up by the wind. Others, such as soot, originate from man's activities, ranging from construction and demolition to combustion and industrial processes. The airborne particles have many sizes and shapes, but we will be dealing only with those large enough to be pulled down to earth by gravity.

Particulate quality may be examined over short- or long-range periods. For the long-range studies of a month or more, students can construct sampling buckets for placement on the school roof, in the classroom, in office buildings, at home, or at any number of locations.

The simplest of these collection devices consists of a gallon container, such as a battery jar or jug, preferably with a mouth diameter of at least four inches. A hand-fashioned wire ring, with a diameter of about 15 inches and mounted about 6 inches above the jar will help spare the experimenter some unwanted contamination in the form of bird droppings.

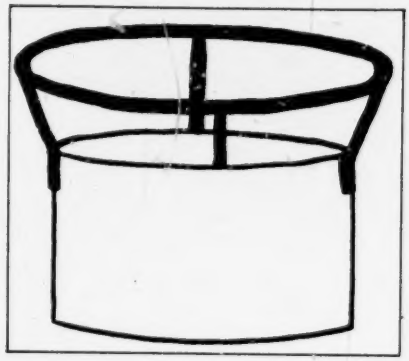


Figure 1 – A long term particulate sampling device which utilizes distilled water as the collecting media.

PROCEDURE

Use distilled water in all steps, including the collection process itself.

Add a few milliliters of 1:1000 zephiran chloride or mercuric chloride solution to the jar to retard any algae growth.

After exposure, screen the collection liquid (to remove feathers, twigs, paper, or other extraneous matter) through 20-mesh screen into preweighed beakers.

Use hot distilled water for rinsing both the collection bottle and the screen.

Reduce the volume of liquid in the beakers by use of a steam bath or hot plate, but do not allow the samples to evaporate to dryness.

Complete the drying in an oven and subtract the weight of the empty beaker from the weight of the same beaker with the collected particulate matter.

Set up a control collecting jar, containing the same amount of water and algicide, but kept tightly capped during the exposure time.

Analyze its contents in the same manner. If any measurable amount of particulate matter is detected in the control, subtract it from that measured in the experimental to provide a more accurate measurement of the particulate matter collected.

It is often useful for comparison purposes to express the collected particulate matter in terms of milligrams/square centimeter/30 days (or some other standard collection time). To find this figure, calculate the area of the jar mouth, using the inside diameter measured to the nearest 0.1 centimeter, and then divide that value into the milligrams of particulate matter collected. If the collection period was 30 days, these calculations give the quantity of particulate matter collected in units of milligrams/square centimeter/30 days.

The variation in quantity of particulate matter collected usually leads into a variety of extensions, ranging from identification of sources, to the relation of wind, weather, seasons of the year, and geographical location to the amounts collected.

Short-Term Studies

Short-term studies, lasting from a fraction of an hour to several days, are easily accomplished either by adhesive capture of particulate matter or by a filter. Any type of material with an adhesive on one side can be used to capture particulate matter, but a transparent material is preferable, since it will allow microscopic examination and comparison to standard photographs for an estimate of particles collected per square inch. Dennison Clear Seal, which is available in precut rectangles or in rolls in most drug or stationery stores, is a very satisfactory material, with a readily removable backing.

One quantitative approach attempts to determine the mass of the particulate matter collected. The size of the collecting surface to be used should be dependent upon the sensitivity of balances that are available and the length of the exposure time. For the most part, mass increases are small, in the vicinity of 0.01 gram in a 2 x 3-inch sheet after 24 hours of typical exposure. Varying either the size of the sheet or the length of exposure time, or both, will allow modifications to meet the balances being used.

Procedures

A simple and satisfactory technique is to mount the adhesive material to walls or solid structures by using a loop of masking tape on the back surface. The orientation of the collecting sheet (horizontally or vertically, including the particular vertical direction of the exposure) is a critical variable. The most versatile collection technique is to mount five sheets on a square or rectangular block of wood, placing one on each of the four sides and the other on the top. Determine the relation of the collected particles to orientation at any given location.

The best quantitative results have been obtained when students mass both the backing sheet and adhesive sheet each time that they make a measurement. If students measure both the mass and the area of their collecting sheets, they will be able to determine the mass increase per unit area for the particular sampling time used. This is a valuable tool for comparison purposes.

An alternative semiquantitative method consists of matching the collected visible particulate density against a photographic standard in order to determine the approximate collection in terms of particles per square inch. A photographic standard is obtainable from Technical Associates For Industry, Inc. (P.O. Box 116, Park Ridge, New Jersey 07656). An exposure time of seven days is recommended for this technique, which takes into account particles in the 20- to 100-micron size range.

For this semiquantitative procedure wrap the adhesive material around a jar or metal or wood cylinder during the collection period. This facilitates a comparison of particulate collection from different directions at the same location. Fix the particles collected by spraying a clear lacquer before removing the adhesive from the collection site. If microscopes are available and a transparent adhesive material has been used, students will be able to observe a large variety of sizes and shapes of captured particles. They may also make a rough map of the area surveyed, showing the particulate collection in either grams/square centimeter or particles/square inch at the collection sites. If there is significant variation, either within the school building or geographic area surveyed, students may be further interested in pursuing the causes of the variation by location.

Complete coverage of a school building, including the wood shop, metal shop, cafeteria, gymnasium, offices, classrooms and laboratories, hallways, and all other feasible collecting areas, is in itself a fruitful undertaking.

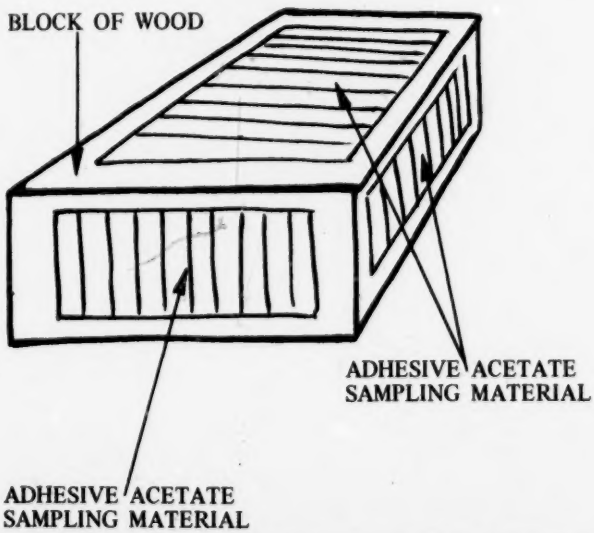


Figure 2 – A short term particulate sampling device that allows students to compare particulate accumulation from five different directions.

Student extensions will probably range from interest in sources and control, to removal and effects, both in terms of public health and on inanimate objects.

Air-filtering experiments

A variety of air-filtering experiments, more complicated than the activities just suggested, are described in many of the laboratory guides listed at the end of the text. For simple qualitative work, however, students may filter air through filter paper or cotton and see staining occur. Laboratory aspirators, vacuum pumps, and vacuum cleaners all provide plenty of air flow. It is also possible to filter the air being exhausted from automobiles and some other sources. However, if students choose to attempt this, **be sure to caution them about the ever-present danger of carbon monoxide from many of these sources.** They should not work in an enclosed space or expose themselves directly to the exhaust blast. Young students should not be allowed to do auto-exhaust studies without adult supervision.

In most urban areas, smokestacks abound—from industry, space heating of buildings, and incinerators. For study of smoke, the Power's MicroRingelmann, an inexpensive device for rough calculation of smoke shade or darkness, is mobile and easily used by students of all ages. These cardboard devices, priced at 75 cents each, are available from Power, 1221 Avenue of the Americas, New York, New York 10020. Complete directions for their use appear on each device. However, a few additional comments are probably in order. Observations on a single source should be made over a minimum 15-minute period, at either 15- or 30-second intervals. The printed direction number 6 on the device is probably best replaced with a simple calculation of the average Ringelmann number for the smoke observed. Record the number of observations from the same source that correspond to each Ringelmann number. After completing all observations for that source, multiply each Ringelmann number by the number of times it was observed. Total all of these products and divide this total by the number of observations.

The quotient, rounded off to the nearest whole number, represents the average Ringelmann number for the particular source during the time observed. For comparison purposes, computations may be rounded to the nearest 0.1. An exciting class activity can consist of all students observing a source of their own choice during the same hour and then comparing the results and identifying the sources during a class discussion.

Data obtained with these devices may complement particulate collection work or lead to a variety of other activities, including discussion and research into why different shades exist. Particles of unburned carbon, along with the gaseous products of combustion, are carried from the stacks. Combustion efficiency and fuel composition are important aspects of modern industrial technology.

THE GASEOUS QUALITY OF THE AIR

The study of gaseous pollutants is more challenging and requires more expensive and sophisticated equipment than is needed for study of particulates. Commercial quality sampling pumps and gas detector tubes represent perhaps the ultimate for classroom work, but they are expensive, ranging from approximately $50 to $100 for a single pump and a few tubes. However, a school seriously undertaking environmental studies should consider the purchase of at least one set. Professional quality sampling can be done by a class or individual when this type of equipment is properly used.

Pumps and testing tubes can be obtained from: Eduquip, Inc. (1220 Adams Street, Boston, Massachusetts 02124), Mine Safety Appliances Company (201 North Braddock Ave., Pittsburgh, Pennsylvania 15208), and National Environmental Instruments, Inc. (P.O. Box 590, Pilgrim Station, Warwick, Rhode Island 02888).

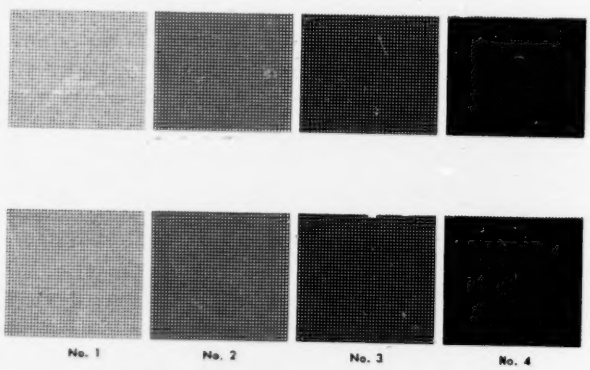


Figure 3 – A Power's MicroRingelmann, a valuable tool for determining smoke shade or darkness.

Rather crude qualitative and/or quantitative measurements of any one of a large variety of different gases, vapors, dusts, fumes, and mists can be made by means of a very inexpensive sampling pump and the appropriate detection tubes.

A satisfactory student-quality pump can be fashioned from a plastic syringe of any volume, though 100 cubic centimeters would be the most desirable size. Most schools already have some of these.

To construct the sampling pump, simply attach a length of rubber tubing whose diameter will accept the glass detector tubes (0.4 or 0.5 centimeter inside diameter tubing will work for most). A short piece of wire will probably be needed to secure the tubing to the syringe. If the volume of the syringe is less than 100 cubic centimeters, an exhaust opening should be cut into the rubber tubing between the tip of the syringe and the end of the inserted glass detector tube. This opening is most easily produced by using a razor

4

blade and cutting a slit perpendicular to the long axis of the tubing. The slit depth should be approximately one-half the diameter of the tubing.

The same gas detection tubes, either "length of stain" or "color intensity" types, used in the more expensive pumps, can be used here. Unfortunately inexpensive student-grade tubes have not to my knowledge appeared on the market yet, so commercial tubes at approximately 50 cents each will still need to be purchased.

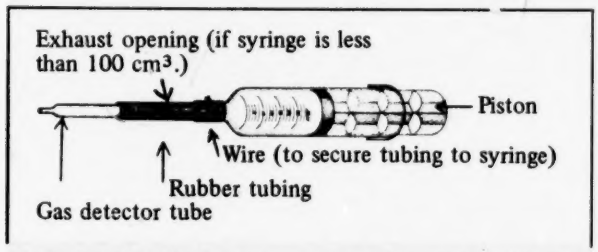
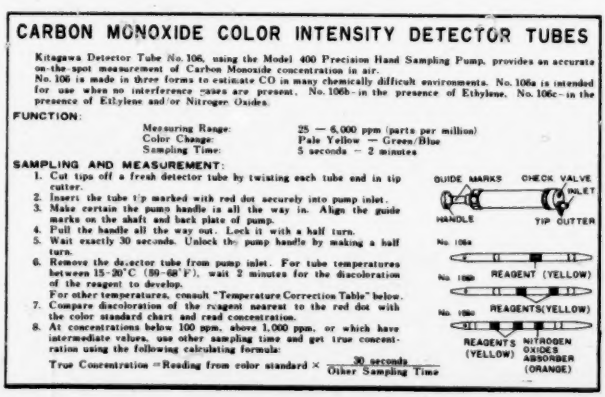


Figure 4 – A sketch of a "gas sampling plastic syringe", which when used with gas detection tubes enables students to detect a wide variety of gaseous pollutants.

Regardless of the type of tubes purchased, read carefully the instruction sheet packed with them. Be particularly careful to note which end of the detector tube is attached to the sampling pump, the volume of air to be sampled, the length of sampling time, the length of the reagent development (waiting) time, and the method of interpreting results.

Once the correct sampling time has been determined, make several practice runs with the pump to insure that the air to be sampled is drawn into the pump at the proper rate (regulated by the rate at which the piston is withdrawn).

Break off the tips of both ends of the sampling tube, insert it into the rubber tubing, and draw the piston back at the proper rate until the desired volume is achieved. If this volume can be reached without having to make more than one pump stroke, the detector tube should be removed as soon as the desired volume is reached.


CARBON MONOXIDE COLOR INTENSITY DETECTOR TUBES

Kitagawa Detector Tube No. 106, using the Model 400 Precision Hand Sampling Pump, provides an accurate on-the-spot measurement of Carbon Monoxide concentration in air.
No. 106 is made in three forms to estimate CO in many chemically difficult environments. No. 106a is intended for use when no interference gases are present. No. 106b- in the presence of Ethylene. No. 106c- in the presence of Ethylene and/or Nitrogen Oxides.

FUNCTION:

Measuring Range:	25 — 6,000 ppm (parts per million)
Color Change:	Pale Yellow — Green/Blue
Sampling Time:	5 seconds — 2 minutes

SAMPLING AND MEASUREMENT:

1. Cut tips off a fresh detector tube by twisting each tube end in tip cutter.
2. Insert the tube tip marked with red dot securely into pump inlet.
3. Make certain the pump handle is all the way in. Align the guide marks on the shaft and back plate of pump.
4. Pull the handle all the way out. Lock it with a half turn.
5. Wait exactly 30 seconds. Unlock the pump handle by making a half turn.
6. Remove the detector tube from pump inlet. For tube temperatures between 15-20°C (59-68°F), wait 2 minutes for the discoloration of the reagent to develop.
   For other temperatures, consult "Temperature Correction Table" below.
7. Compare discoloration of the reagent nearest to the red dot with the color standard chart and read concentration.
8. At concentrations below 100 ppm, above 1,000 ppm, or which have intermediate values, use other sampling time and get true concentration using the following calculating formula:

True Concentration = Reading from color standard × 30 seconds / Other Sampling Time

GUIDE MARKS CHECK VALVE INLET HANDLE TIP CUTTER
No. 106a
No. 106b REAGENT (YELLOW)
No. 106c REAGENTS(YELLOW)
REAGENTS (YELLOW) NITROGEN OXIDES ABSORBER (ORANGE)

If more than one pump stroke is necessary, use the exhaust vent. Just before beginning the exhaust stroke, pinch the rubber tube off between the exhaust vent and the detector tube and bend the tubing to provide as large an opening as possible for the exhausting gases. When all the air has been exhausted and the operator is ready for another intake stroke, release the rubber tube and allow it to straighten out.

After removing the tube, observe the proper waiting time. Then match either the "length of stain" or "color of stain" against the calibration chart packed with each package of tubes in order to determine the concentration.

Special safety precautions must be taken when students are breaking off the tips of the gas-detector tubes. Without proper precautions, glass cuts can result. Some manufacturers provide small rubber tips to aid in breaking off the ends, but others provide nothing. You may want to design some "tube breakers" for your students. A small piece of metal with an appropriate size hole (0.3 centimeter is adequate) drilled into it will serve nicely. Students should always have their hands protected (by toweling or handkerchief) and exert pressure close to the area where the break should occur. The tubes should be broken as close to the narrow diameter ends as possible.

The types of activities that can be undertaken by a student armed with sampling pump and detector tubes are very broad indeed.

For example, the city air can be sampled and the presence and/or concentration of any number of selected pollutants (CO, SO_2, NO_2, and a host of others) over short or extended periods of time can be monitored. Carbon monoxide (CO) readings may be taken every hour at a busy intersection, for example, to see what effect traffic density has on the quality of the air and whether or not the concentration exceeds minimum health standards. Your local air pollution control agency should be contacted for this type of information.

Stack or auto exhaust emissions can be tested for CO or other pollutant concentrations and comparisons may be

Color Standards for CARBON MONOXIDE

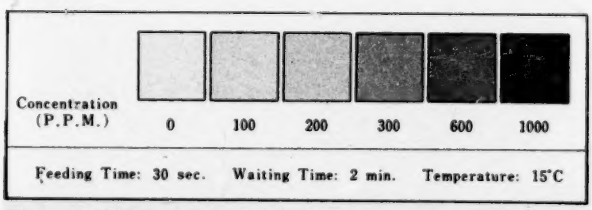


Figure 5 – Instructions and color-standard chart for color intensity carbon monoxide detector tubes.

made between old and new vehicles, tuned and untuned samples, and those with and without pollution control devices. Buses, trucks, and motor bikes could likewise be checked. However, if students decide to check auto exhausts, **caution them against checking in an enclosed space or getting their faces close to the exhaust pipe or other source.**

Since many gaseous air pollutants are the result of incomplete combustion, cigarette smoke is an excellent source of smoke for classroom study. A simple smoking machine can be constructed from a pipette with a rubber bulb. A length of rubber tubing that will securely accept cigarettes (0.6 centimeter inside diameter will suffice for most types) is placed over the end of the pipette.

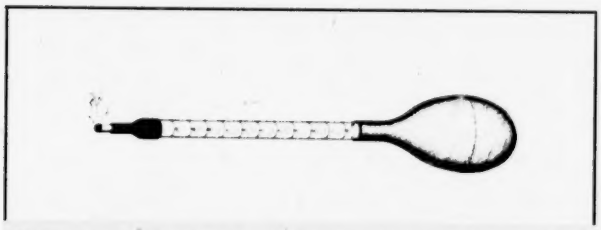


Figure 6 – A sketch of a pipette "smoking machine", an ideal classroom source of air pollutants.

Adequate smoking of the cigarettes is obtained by manipulating the bulb at the desired rate. Smoke sampling can be accomplished either at the cigarette end or within the pipette (by removing the bulb), which often provides answers to some student questions concerning the effectiveness of filters.

Concentrations of CO will probably be in the vicinity of 500 to 1,000 parts per million (ppm) when measurements are taken near the tip of the burning cigarette or within the pipette, and experience has shown that the syringe type of pump tends to give results that are somewhat higher than those obtained by using professional equipment, dependent largely upon the skill of the operator in manipulating the piston. The rate of flow of the air to be tested as it passes through the detection tube appears to be the most critical factor.

Many rather creative classroom activities have been performed utilizing cigarettes of different brands, and of filters and nonfilters, with the students comparing test results.

EXPLORING URBAN WATER

Interest in water, a biological necessity for life as we know it, can usually motivate urban students. The forces that historically have governed urban growth and development have usually resulted in cities being located on or near a river, lake, or other body of water. Students may be interested in further pursuing these causes, since they have played a major role in catalyzing many of our most pressing water-quality problems.

Various and inviting student projects are associated with urban water resources. The most obvious and basically informative of these deals with sources and treatment prior to use, uses and effects of this use, and treatment facilities and processes following use.

Perhaps the most valuable single activity in which a teacher could involve his class would be a field trip to the nearest sewage treatment facility. A trip of this type greatly aids students in putting into proper perspective the quantity of water requiring treatment in an urban area. In addition, a great many fundamental concepts of science and technology will be found operative in the plant as the student follows the treatment process. Plant operators and sanitary engineers can engage students in interesting, factual conversation regarding problems–whether in treatment of petroleum wastes, regarding phosphates, or about other facets of the treatment process.

Most disposal and treatment system funding comes from user taxes, and certainly we can aid our students in some first-hand information-gathering that will help them become better informed water users and scientifically sensitive voters.

The biological survey of life in a body of water, as always, is valuable. Records kept over the years on the same body of water (using the same testing sites and procedures) may show definite changes in this aquatic population that can be linked to changes in water quality.

Another study can determine the effects that changes in the aquatic environment have on certain living organisms. *Daphnia,* tubifex worms, and mosquito larvae, for example, are all well suited as subjects for this type of activity. With these organisms it is possible to observe a variety of effects, in particular the change in heartbeat rate.

The effects of temperature changes, as well as the effects of the addition of different substances represent a fertile exploration. Students may add such substances as alcohols, pulp mill or other industrial discharges, fertilizers, detergents, pesticides, salts, acids, bases, petroleum products, or sediments.

For a limited water-quality survey, certain aspects of the quality of water in rivers, streams, ponds, lakes, accumulated surface waters, and storm sewers, are rather easily examined.

Experience has shown that while students often want to examine a large number of aspects of water quality, they obtain the most productive and meaningful results if they limit themselves to one or a few, at least for their beginning investigation.

6

WATER POLLUTION–A NEW PROBLEM?

Water pollution is as old as, if not older than, civilization itself. Silt is probably the world's oldest pollutant of water, since it was present long before man and has been aggravated by man's activities.

It was about the middle of the nineteenth century before the role of polluted drinking water in the spread of diseases such as cholera, typhoid fever, hepatitis, and dysentery was discovered. Even so, it was 1899 before the first recorded federal legislation in the United States was enacted to control water quality. This was the famous River and Harbors Act, which prohibited the discharge or deposit into any navigable waters of any refuse except that which flowed from streets or sewers in a liquid state.

The total use of water today in the United States is over 355 billion gallons per day, with an anticipated increase to about 600 billion gallons per day by 1980. The typical large city presently uses more than 70 million gallons of water per day.

AN INEXPENSIVE WATER-TESTING KIT

A small, mobile, relatively inexpensive water-testing kit can be put together for student use.

It should include:

Inexpensive pH paper, with color-matching pH chart. A nice model, sold under the trade name of pHydrion papers by Micro Essential Laboratory (Brooklyn, New York 11210), is self-contained in a plastic dispenser.

Simple thermometer, either laboratory type or home type. Students should be cautioned, about the hazards associated with mercury, if mercury-filled thermometers are used.

Combination water depth–water temperature device.
Solutions in dropper bottles.
See list on page 9.
Instructions on file cards.
10 small test tubes.

Such a kit will allow simple, qualitative testing for a number of important constituents of water, which should be quite satisfactory for beginning work. References at the end of the text provide numerous sources of information for conducting other tests and/or quantification for some of those used. A total of six tests may be performed utilizing this kit.

Perhaps the simplest test is a semiquantitative test for pH. It determines relative acidity or alkalinity as measured by hydrogen-ion concentration.

Test for pH

Students simply immerse the paper in the water to be tested and match the color obtained to determine an estimate of the pH. The lower the pH number, the higher the hydrogen-ion concentration or acidity.

The pH variation within a body of water or between neighboring bodies of water can be due either to natural causes or to waste discharge. It is generally considered advisable to view with suspicion any waters, particularly stream waters, having a pH outside the approximate limits of 7.0-8.5. This is particularly so if the cause can be found to be other than natural factors.

Acid or base waste discharges or chemical reactions occurring within water can produce striking changes in the pH. Considerable acidity may result from pollution traced to chemical works, fertilizer factories, bleaching plants, creameries, battery factories, unsealed coal mines, and a host of other sources.

Water Temperature

Another straighforward test is that for water temperature. Water temperature is affected by a variety of factors, including depth, flow rate, waste and organic matter present, and shading. The combination water-depth-water-temperature device used by fishermen is a very handy tool for this work, and it can be purchased inexpensively at nearly any hardware-outdoor store.

Students examining water temperature along a stream or lake shore should be encouraged to keep as many of these variables as possible constant, and certainly to keep accurate records whenever they vary. If this is not done, the results will be very difficult to use as generalizations.

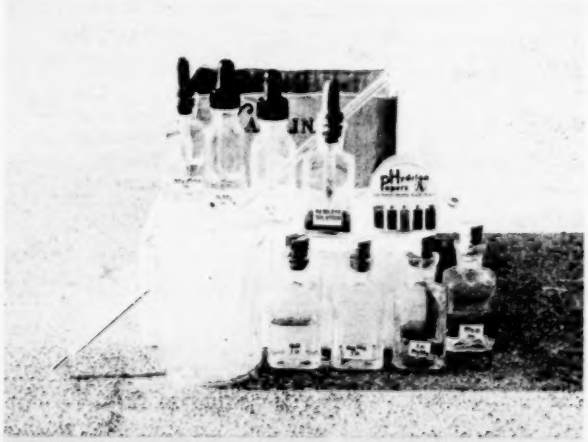


Figure 7 – Students can utilize this small, mobile, relatively inexpensive water-testing kit to make six different meaningful tests.

Temperature Stratification

A particularly interesting activity is to determine the temperature stratification in streams, ponds, lakes, and other bodies of water. The temperature variation with depth has a pronounced effect upon dissolved gases, particularly oxygen and carbon dioxide, and is useful when combined with a study of the biological populations found at the various depths.

Chemical Tests

The next several tests are chemical in nature, and the degree of student understanding of the mechanism of the chemical reactions involved is largely related to the use within the school. If the tests were being run by high school chemistry students, it would be logical to expect the mechanisms to be understood as a complement to the chemistry being studied. However, if the tests were being run in a sixth-grade class, it would probably serve no useful purpose to become involved in the mechanism. The results are equally useful in either situation.

The necessary ingredients for completing these tests may be included in the kit, probably most usefully by putting the various solutions in small, labeled dropper bottles. The entire set may be transported in a small cardboard box, together with the temperature-measuring device and the pH paper. Student instruction sheets can be mimeographed, cut into convenient sizes, and then pasted to file cards to be placed in the kit.

All tests utilize approximately one-fourth of a small test tube volume of water or other solution to be tested. A complete list of the chemicals needed and instructions for preparation of 1 liter of each solution is given on page 9.

A test for the presence of phosphates, the result of natural processes, waste disposal (laundry detergents), runoff from fertilized agricultural land, or from a host of other sources may be made by using a few drops of 6 N nitric acid (HNO_3) and about 10 drops of 1 N ammonium molybdate ($(NH_4)_2MoO_4$) solution.

To see a positive test, add to about one-fourth test tube of .3 M sodium phosphate (Na_2HPO_4) the nitric acid and ammonium molybdate. A yellow ammonium phosphomolybdate ($(NH_4)_3PO_4 \cdot 12\ MoO_3$) compound will be gradually precipitated. Warming in a water bath for five minutes or so may be required to help produce the reaction.

Phosphates are one of several categories of pollutants that are potent plant nutrients. They fertilize aquatic plant life, such as algae and water weeds, thereby changing the quality of the water by increasing both their numbers and their oxygen demand upon decaying.

A variety of salts may be present in water, due to natural causes, waste disposal, or surface contamination. Although these salts may not be toxic, it is often important to be aware of their presence so that they can be removed for certain uses of the water.

Many of these salts are chlorides, and we may check for the presence of chlorides by testing with 3 to 4 drops of 1 M silver nitrate ($AgNO_3$) solution. To observe a positive test, add to about one-fourth test tube of 1 M sodium chloride (NaCl or table salt) solution to the silver nitrate. A white, curdy precipitate of silver chloride (AgCl) will be observed.

The chloride ion (Cl^-) which we have tested for is one of the major anions in water and sewage. It may rather specifically be derived from mineral deposits (natural), from ocean vapors carried inland by the wind and saltwater invasion of fresh water areas (natural), from oil field wastes, from sewage, and from industrial wastes. Local sewage pollution of well water is often first evidenced by an increased chloride content.

Small amounts of ammonia can be found where it is formed by the decaying of plant and animal materials. Three or four drops of Nessler's reagent can be used to check for its presence.

To observe a positive test, add the Nessler's reagent to about one-fourth test tube of 3 M ammonium chloride (NH_4Cl). A red-orange to rust colored or brown precipitate will be formed.

Sulfates, from either surface contamination (such as fertilizer runoff), industrial waste discharge, or natural causes, may be detected by testing a water sample with three or four drops of 1 M barium chloride ($BaCl_2$) solution. So called "hard water" usually contains sulphate.

To observe a positive test, add the barium chloride test solution to about one-fourth test tube of .3 M sodium sulphate (Na_2SO_4). A fine, white precipitate will give the solution tested a milky appearance.

Certain of the compounds used, as indicated on the container labels (mercuric chloride for example) are toxic. Students should be instructed to treat all of their solutions as toxic, in order to develop good working habits and insure safety.

SOME OTHER IDEAS

There are many other facets of water quality that can be studied by students, ranging from relatively simple to moderately sophisticated inquiry excursions. Samples of water may be monitored for radioactivity, for example, using any number of detection devices. This may be a particularly pertinent study for students living in areas with

operative nuclear power plants or industrial complexes that utilize radioactive materials or produce radioactive wastes.

Turbidity, which is due to suspended matter such as clay, silt, finely divided organic matter, microscopic organisms, and similar materials, is measured in terms of the passage of light through the water sample. The standard instrument for making such measurements is the Jackson candle turbidimeter, even though a newer technique has been developed using observations of a platinum wire.

One of the most important qualities of water is the dissolved oxygen content, and for fish it is probably the single most important factor in their aquatic environment. The measurement of dissolved oxygen is of necessity a quantitative test, and the procedures involved are considerably more rigorous than any mentioned up to this point. It is probably a determination that is best done by students following an introductory series of simpler tests. The basic Winkler procedure or the Rideal-Stewart modification is that most often used, and it is outlined in literally every reference dealing with water quality determination. Frequent reference is made to the bacterial quality, in terms of both types and count, of water. This is particularly evident when areas are reported as being closed to swimming, or when well water is being checked for potable purposes.

The bacillus *Escherichia coli,* which is a common intestinal inhabitant of man, is a good indicator of pollution. Generally speaking, flowing oxygenated water is an unfavorable habitat for *Escherichia coli,* and its degree of presence indicates a relatively near and recent source of pollution.

Work can be done in the area of bacterial examination of water, but care must be taken, and both students and teachers should be well-informed before undertaking this type of study.

Environmental studies are certainly not a single subject nor the property of a given classroom or teacher. Their inclusion is appropriate and complementary in any course. Interdisciplinary study should promote an even deeper understanding of the environment.

CHEMICALS

Quantities, to the nearest 50 grams or milliliters, of chemicals needed to prepare 1 liter of each of the water test kit solutions are indicated below. Approximately 50 student kits could be assembled from 1 liter of stock solutions.

500 ml concentrated nitric acid (HNO_3)
100 g ammonium molybdate ($(NH_4)_2MoO_4$)
50 g sodium phosphate (Na_2HPO_4)
200 g silver nitrate ($AgNO_3$)
100 g sodium chloride (NaCl)
50 g potassium iodide (KI)
50 g mercuric chloride ($HgCl_2$)
200 g sodium hydroxide (NaOH)
200 g ammonium chloride (NH_4Cl)
250 g barium chloride ($BaCl_2$)
50 g sodium sulphate (Na_2SO_4)

Instructions for preparing 1 liter stock solutions of each of the desired concentrations of water test kit components:

6 N nitric acid (HNO_3): Dilute 380 ml of concentrated nitric acid with distilled water to 1 liter. *Remember to add acid to water.*

1 N ammonium molybdate ($(NH_4)_2MoO_4$): Dissolve 98 g of solid ammonium molybdate in distilled water and dilute to 1 liter.

.3 M sodium phosphate (Na_2HPO_4): Dissolve 43 g of solid sodium phosphate in distilled water and dilute to 1 liter.

1 M silver nitrate ($AgNO_3$): Dissolve 170 g of solid silver nitrate in distilled water and dilute to 1 liter.

1 M sodium chloride (NaCl): Dissolve 59 g of solid sodium chloride in distilled water and dilute to 1 liter.

5 N sodium hydroxide (NaOH): Dissolve 200 g of sodium hydroxide in distilled water and dilute to 1 liter.

3 M ammonium chloride (NH_4Cl): Dissolve 161 g of solid ammonium chloride in distilled water and dilute to 1

1 M barium chloride ($BaCl_2$): Dissolve 208 g of solid barium chloride in distilled water and dilute to 1 liter.

.3 M sodium sulphate (Na_2SO_4): Dissolve 43 g of solid sodium sulphate in distilled water and dilute to 1 liter.

Nessler's Reagent: Dissolve 50 g of solid potassium iodide (KI) in approximately 50 ml of *cold* distilled water. Add a saturated solution of mercuric chloride ($HgCl_2$), prepared by dissolving about 22 g of mercuric chloride in 350 ml of distilled water, until the orange precipitate being formed can no longer be dissolved by stirring or agitating. Then add 200 ml of 5 N sodium hydroxide (NaOH) and dilute the solution to 1 liter, using distilled water. Let the solution settle and draw off the clear liquid (it may have a slight orange tint) for use in the student kits.

SOURCE LIST

This listing should be used as information and should not be considered a recommendation. No endorsement is intended by this list, and any omissions are inadvertent.

Agencies for Information

Department of Health, Education, and Welfare
Environmental Control Administration
12720 Twinbrook Parkway
Rockville, Maryland 20852

Environmental Protection Agency
Public Inquiries Branch
Washington, D.C. 20460

Office of Information
U.S. Atomic Energy Commission
Washington, D.C. 20545

Office of Information
U.S. Department of Agriculture
Washington, D.C. 20250

United States Atomic Energy Commission
Technical Information Center
P.O. Box 62
Oak Ridge, Tennessee 37830

Private Organizations

Air Pollution Control Association
4400 Fifth Ave.
Pittsburgh, Pennsylvania 15213

American Association for the Advancement of Science
1515 Massachusetts Ave., N.W.
Washington, D.C. 20036

American Cancer Society
219 E. 42nd Street
New York, New York 10017

American Fisheries Society
1040 Washington Bldg.
15th Street and New York Ave., N.W.
Washington, D.C. 20005

American Petroleum Institute
1801 K Street, N.W.
Washington, D.C. 20006

Automobile Manufacturers Association, Inc.
320 New Center Building
Detroit, Michigan 48202

League of Women Voters of the United States
1730 M Street
Washington, D.C. 20036

National Association of Conservation Districts
1025 Vermont Ave., N.W.
Suite 1105
Washington, D.C. 20005

Sierra Club
1050 Mills Tower
220 Bush Street
San Francisco, California 94104

Periodicals

Air Pollution Control Association Journal, Air Pollution Control Association, Pittsburgh, Pennsylvania
American City Magazine, Buttenheim Publishing Corporation, Pittsfield, Massachusetts
Atmospheric Environment, Maxwell House, Elmsford, New York
Audubon Magazine, National Audubon Society, New York, New York
British Columbia Outdoors, Surrey, Cloverdale, British Columbia, Canada
Chemical and Engineering News, American Chemical Society, Washington, D.C.
Current Science, American Education Publications, Columbus, Ohio
Desalination, Elsevier Publishing Company, Amsterdam, Netherlands
Ecological Monographs, Duke University Press, College Station, Durham, North Carolina
Ecology, Duke University Press, College Station, Durham, North Carolina
Environment, Committee for Environmental Information, St. Louis, Missouri
Environmental Education, Dembar Educational Research Services, Inc., Madison, Wisconsin
Environmental Science and Technology, American Chemical Society Publications, Washington, D.C.
Journal of Environmental Health, National Environmental Health Association, Denver, Colorado
Journal of Soil and Water Conservation, Soil Conservation Society of America, Ankeny, Iowa
Journal of the Water Pollution Control Federation, Water Pollution Control Federation, Washington, D.C.
Natural History, American Museum of Natural History, New York, New York
Oceanology International, Aviation Division of Ziff-Davis Publishing Company, Washington, D.C.
Oceans, Oceans Magazine, San Diego, California
Pollution Abstracts, La Jolla, California
Public Works Magazine, Public Works Journal Corporation, Ridgewood, New Jersey
Radiological Health Data and Reports, U.S. Public Health Service, Washington, D.C.

10

Science, American Association for the Advancement of Science, Washington, D.C.

Science Activities, Science Activities Publishing Company, Skokie, Illinois

Scientific American, Scientific American, Inc., New York, New York

Sierra Club Bulletin, San Francisco, California

The Science Teacher, National Science Teachers Association, Washington, D.C.

Today's Health, American Medical Association, Chicago, Illinois

Water and Wastes Engineering, New York, New York

Water Research, International Association on Water Pollution Research, Elmsford, New York

Water Resources Research, American Geophysical Union, Washington, D.C.

Activity and Experiment Sources

Air Pollution Experiments for Junior and Senior High School Science Classes. Hunter and Wohlers, Editors. Air Pollution Control Association, Pittsburgh, Pennsylvania. 1969. $1 (10 or more copies 50¢ each).

Air Pollution Experiments, High School Edition. Edited by Prof. Joseph J. Soporowski, Jr. Cooperative Extension Service, College of Agriculture and Environmental Science, Rutgers University, New Brunswick, New Jersey. Free.

Detection and Analysis of Particulate Contamination. Millipore Corporation, Bedford, Massachusetts. 1969. Free.

Environmental Education–Objectives and Field Activities. Major Cissell and others. Paducah Public Schools, Environmental Education, Paducah, Kentucky. 1969. Single copies $5.

Environmental Pollution. Experiences/Experiments/Activities. Elbert C. Weaver. Holt, Rinehart & Winston, Inc., New York. 1971. $0.93 net to schools. Also Teachers Manual.

Experiments in Microbiology. Millipore Corporation, Bedford, Massachusetts. 1969. $0.50.

FWPCA Methods for Chemical Analysis of Water and Wastes. U.S. Department of the Interior, Federal Water Pollution Control Administration, Division of Water Quality Research, Analytical Quality Control Laboratory, Cincinnati, Ohio. 1969.

Investigating Water Problems: A Water Analysis Manual. Charles E. Renn, LaMotte Chemical Products Company, Chestertown, Maryland. 1971. $0.50.

Limnology: An Introduction to the Fresh Water Environment. William H. Amos. LaMotte Chemical Products Company, Chestertown, Maryland. 1969. $0.50.

Microbiological Analysis of Water. Millipore Corporation, Bedford, Massachusetts. 1969. Free.

Our Environment Battles Water Pollution. Charles E. Renn, LaMotte Chemical Products Company, Chestertown, Maryland. 1969. $0.50.

Scientific Experiments in Environmental Pollution. Elbert C. Weaver, Editor. Manufacturing Chemists Association, Holt, Rinehart & Winston, Inc., New York, New York. 1968. $0.93 net to schools. Also Teachers Manual.

Some Air Pollutant Estimation Techniques for the High School Science Student. Laboratory of Atmospheric Sciences, National Center for Atmospheric Research, Boulder, Colorado.

Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, D.C.

A Study of Water Quality. Charles E. Renn, LaMotte Chemical Products Company, Chestertown, Maryland. 1969. $0.50.

Bibliographies, Dictionaries, Directories, Lists, & Catalogs

Air Pollution Publications 1966-68 (PHS Publication No. 979). Public Health Service, Washington, D.C. 1969. $4.50.

Available Curriculum Materials, A List. Minnesota Environmental Sciences Foundation, Inc., Minneapolis, Minnesota.

Catalog of Free Films on Air Pollution on Loan for Group Showings. U.S. Government Printing Office, Washington, D.C.

Dictionary of Ecology. Herbert C. Hanson. Philosophical Library, Inc., New York, New York. 1962. $10.00.

"Bibliography on Air and Water Pollution," *Special Libraries* 57: 6; July-August 1966. Pp. 385-390. Special Libraries Association, New York, New York. $1.50.

Science for Society, A Bibliography. John A. Moore, Commission on Science Education, American Association for the Advancement of Science, Washington, D.C. $1 per copy (10 or more copies 75¢ each).

OTHER TITLES IN THE SERIES

How to Plan and Organize Team Teaching in elementary school science
(Stock No. 471-14594) L. Jean York

How to Teach Measurements in elementary school science
(Stock No. 471-14580) Neal J. Holmes and Joseph J. Snoble

How to Use Chromatography as a science teaching aid
(Stock No. 471-14578) Frank M. Ganis

How to Use Behavioral Objectives in science instruction
(Stock No. 471-14596) John J. Koran, Jr., Earl J. Montague, and Gene E. Hall

How to Provide for Safety in the Science Laboratory
(Stock No. 471-14576) James R. Irving

How to Use an Oscilloscope
(Stock No. 471-14572) Morris R. Lerner

How to Use Photography as a science teaching aid
(Stock No. 471-14560) Herman H. Kirkpatrick

How to Evaluate Science Learning in the elementary school
(Stock No. 471-14564) Paul E. Blackwood and T. R. Porter

How to Utilize the Services of a Science Consultant . . . to improve school science programs
(Stock No. 471-14286) Kenneth D. George

How to Care for Living Things in the Classroom
(Stock No. 471-14288) Grace K. Platt

How to Record and Use Data . . . in elementary school science
(Stock No. 471-14292) Mary Clare Petty

How to Individualize Science Instruction in the elementary school
(Stock No. 471-14294) Theodore W. Munch

How to Present Audible Multi-Imagery in environmental ecological education
(Stock No. 471-14614) Pascal L. Trohanis

How to Handle Radioisotopes Safely
(Stock No. 471-14616) John W. Sulcoski and Grafton D. Chase

How to Study the Earth From Space
(Stock No. 471-14624) Robert E. Boyer

Others in preparation. Consult your NSTA publications list.

Order direct from NSTA, 1201 Sixteenth Street, N.W., Washington, D.C. 20036. Price per copy: 35 cents. *Discounts: 2-9 copies, 10 percent; 10 or more copies, 20 percent. Payment must accompany all orders except those on official purchase order forms. Postage and handling charges will be added to billed orders.

*Except *How to Use an Oscilloscope* and *How to Handle Radioisotopes Safely*, $1 each; *How to Present Audible Multi-Imagery*, *How to Read the Natural Landscape* and *How to Study the Earth From Space*, 50¢ each.